(12) UK Patent Application (19) GB (11) 2 265 024 (13) A

(43) Date of A publication 15.09.1993

(21) Application No 9205660.5

(22) Date of filing 14.03.1992

(71) Applicant
British Aerospace Public Limited Company

(Incorporated in the United Kingdom)

11 The Strand, London, WC2N 5JT, United Kingdom

(72) Inventor
Geoffrey Martland Proudley

(74) Agent and/or Address for Service
Paul Blaise Rooney
British Aerospace Public Limited Company,
Corporate Intellectual Property Dept,
Lancaster House, Farnborough Aerospace Centre,
Farnborough, Hants, GU14 6YU, United Kingdom

(51) INT CL[5]
G02F 1/01, G02B 26/02

(52) UK CL (Edition L)
G2F FCH F25G F26R F26X

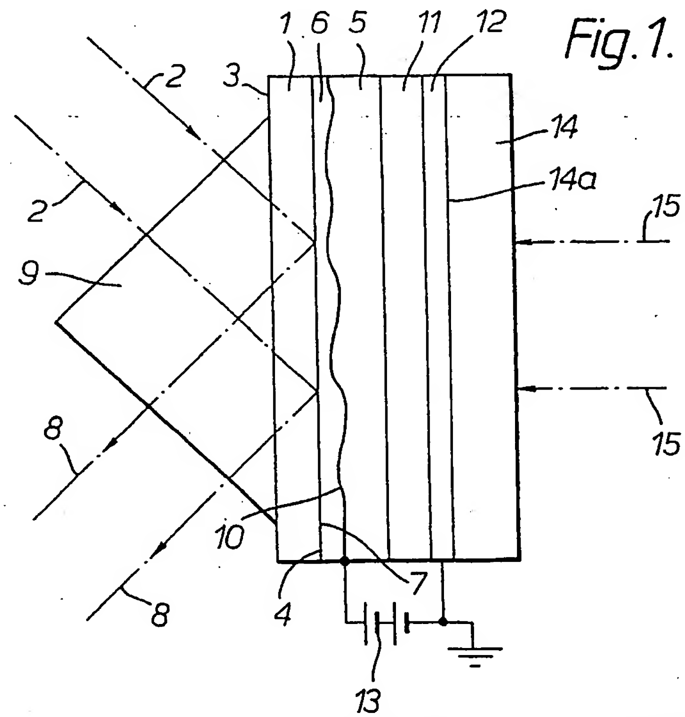
(56) Documents cited
GB 2238880 A

(58) Field of search
UK CL (Edition K) G2F FCH
INT CL[5] G02B, G02F
Online databases: WPI, CLAIMS

(54) **A spatial light modulator assembly**

(57) A spatial light modulator assembly has a layered sandwich form. The assembly includes a first layer (1) of material transparent to a read in beam (2) of light, a second layer (5) of a deformable material which is physically deformable in response to variation in an electrostatic field temperature or a potential difference, and, located in a gap (6) between the second layer (5) and the inner surface (4) of the first layer (1) a gaseous medium such as air having a lower refractive index than that of the first layer (1). The gaseous medium forms an interface (7) with the first layer at which a laser light read in beam (2) passing into the first layer (1) is amplitude modulated by modulation of the gap (6), and thereby of the reflection coefficient at the interface (7), resulting from deformation of the deformable material.

Fig. 1.



At least on drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

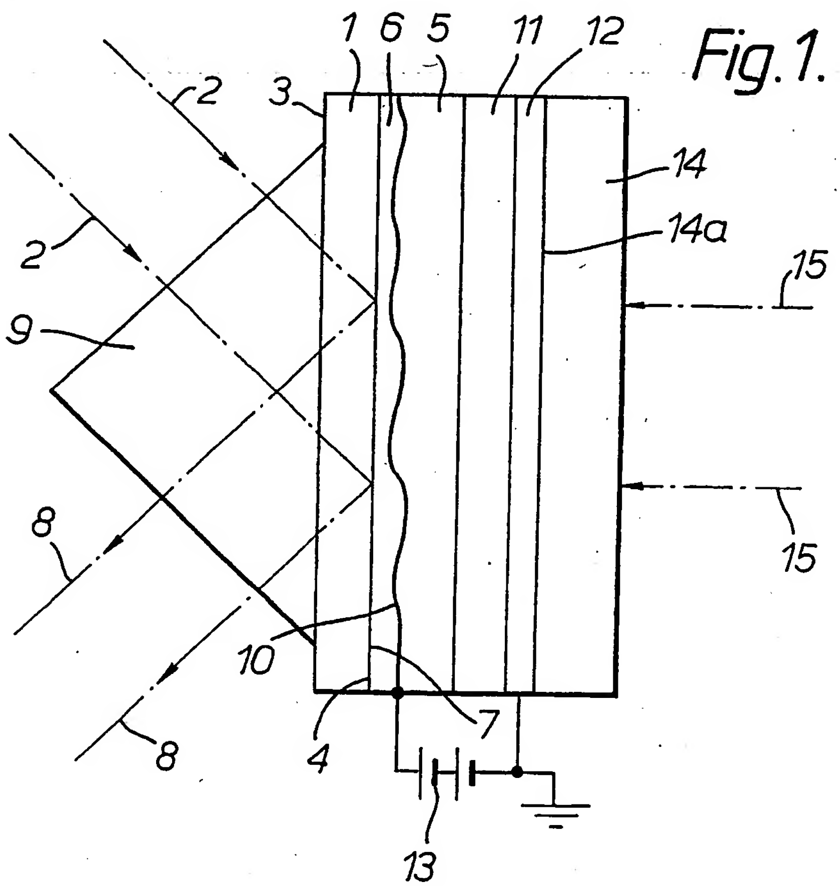
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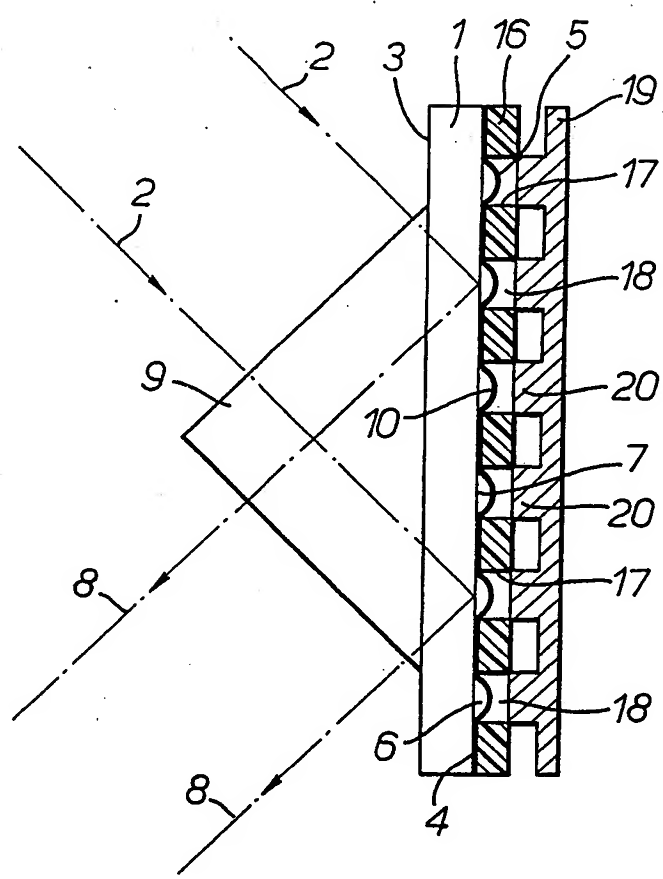
Fig.2.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A SPATIAL LIGHT MODULATOR ASSEMBLY

This invention relates to a spatial light modulator assembly of layered sandwich form particularly, but not exclusively, suitable for imposing information on a light read beam such as a laser light read beam.

A spatial light modulator assembly is known which utilises a deformable surface to impose information on a read out laser beam. In such a known assembly a charge pattern or local electric field variation is generated across the deformable surface by photo generation or electronically. However in such a known assembly there is the disadvantage that the read-out laser beam interacts with the deformable surface, either by being reflected off it in some way or by being transmitted through it. This means that the optical quality of the deformable surface material is critical, especially in transmission mode. Whether reflected or transmitted by the deformable surface the read out laser beam travels through slightly different optical path lengths from each point and thus phase modulation occurs across the beam. This makes it necessary for the beam to undergo some process for converting this phase modulation into amplitude modulation to get a binary black and white or grey level image. Thus such a known spatial light modulator assembly has the drawback of causing beam distortion and of requiring conversion from phase to amplitude modulation. A solution to both these problems would considerably improve the usefulness of such a modulator assembly.

There is thus a need for a spatial light modulator assembly which at least minimises the foregoing disadvantages.

According to one aspect of the present invention there is provided a spatial light modulator assembly of layered sandwich form, including a first layer of material transparent to a read beam of light, which first layer has an outer surface through which, in operation, an impinging read in beam of light passes into the first layer, and an inner surface, a second layer of a deformable material which is physically deformable in response to variation in an electro-static field, temperature or a potential difference, and, located in a gap between the second layer and the inner surface of the first layer, a gaseous medium having a lower refractive index than that of the first layer, which gaseous medium, in operation of the assembly, forms an interface with the first layer inner surface at which the light read in beam passing into the first layer through the outer surface thereof is amplitude modulated by modulation of the gap, and thereby of the reflection coefficient of the interface, resulting from deformation of the deformable material and substantially totally reflected, as a amplitude modulated read out beam, back through the outer surface of the first layer.

Preferably the gaseous medium is air having a refractive index of substantially 1.0.

Conveniently the first layer material has a refractive index in the range of from 1.5 to 2.0.

Advantageously the first layer material is a glass or an optical polymer, and the outer and inner surfaces are substantially planar and substantially parallel to one another.

Preferably the assembly includes a prism made of light transparent material, preferably laser light transparent material, substantially refractive index matched to the first layer material associated with or and attached to the other surface of the first layer to assist in addressing the interface at high angles and reducing refraction.

Conveniently the assembly includes anti-reflection coatings on at least the two external faces of said prism.

Advantageously the second layer deformable material is at least one of a elastomer, gel, membrane, incompressible fluid, oil film or thermoplastic.

Preferably the assembly includes a third layer in the form of a metallic coating, which is non-transparent to light, preferably laser light, preferably on a surface of the second layer which faces the gaseous medium and forms a boundary therewith to the gap, which third layer is an electrode and of sufficient optical density to absorb any transmitted read in beam laser light.

Conveniently the metallic coating is made of gold or a gold alloy.

Advantageously the assembly includes a fourth layer adjoining the surface of the second layer most remote from the third layer, which fourth layer is made of a photoconductive material.

Preferably the fourth layer material is at least one of silicon, cadmium sulphide, zinc sulphide, zinc cadmium sulphide, and PVK-TNF (a combination of Poly-n-Vinylcarbozole and a dye 2, 4, 7 trinitrofluorenone).

Advantageously the assembly includes a fifth layer of an electrode material, transparent to light, preferably laser light, located adjacent to and in contact with the surface of the photoconductive fourth layer most remote from the second layer which fifth layer is coupled to the third layer by a source of electrical energy.

Advantageously the assembly includes a sixth layer of material which is transparent to a write beam of light, preferably laser light, which sixth layer has an inner face adjacent to or in contact with the outer face of the fifth layer most remote from the fourth layer.

Preferably the sixth layer is made of glass or an optical polymer.

Alternatively the second layer is a membrane.

Conveniently such an alternative assembly includes a spacer layer made of insulating material and provided with a plurality of holes therethrough forming cells or pixels bridged by said second layer, which spacer layer is in contact with the surface of the second layer most remote from the gap.

Advantageously such an alternative assembly includes an electrode layer made of electrically conductive material and having a plurality of spaced apart protrusions on one surface thereof forming an array of electrodes, which electrode layer is

so located adjacent to said spacer layer on the side thereof most remote from the second layer, that the electrode protrusions lie one at the base of each hole in the spacer layer so that with the third layer being held at a substantially constant potential and with each electrode in the array being driven by addressing electronics to a voltage corresponding to a desired value, a potential difference between the electrodes and the third layer causes deflection of the second layer towards or away from the interface to amplitude modulate the read out beam.

Preferably the read in beam and/or read out beam is or are of laser light.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is an end view of a spatial light modulator assembly according to a first embodiment of the present invention, and

Figure 2 is a partially sectioned view from one end of a spatial light modulator assembly according to a second embodiment of the present invention.

A spatial light modulator assembly of the present invention is shown in the accompanying drawings in Figures 1 and 2 thereof. In basic format the modulator assembly is of layered sandwich form including a first layer 1 of material transparent to a read in beam 2 of light, preferably laser light. The first layer 1 has an outer surface 3 through which, in operation, the

impinging read in beam 2 of laser light passes into the first layer 1 and an inner surface 4.

The assembly includes a second layer 5 of a deformable material which is physically deformable in response to variation in an electrostatic field, temperature or a potential difference and, located in a gap 6 between the second layer 5 and the inner surface 4 of the first layer 1, a gaseous medium having a lower refractive index than that of the first layer. In operation of the assembly the gaseous medium in the gap 6 forms an interface 7 with the first layer inner surface 4 at which the laser light read in beam 2 passing through the first layer 1 through the outer surface 3 thereof is amplitude modulated by modulation of the gap 6, and thereby of the reflection coefficient at the interface, resulting from deformation of the deformable material of the second layer 5 and substantially totally reflected, as an amplitude modulated read out beam 8, back through the outer surface 3 of the first layer 1.

Preferably the gaseous medium is air having a refractive index of substantially 1.0. The material of the first layer 1 has a refractive index higher than that of the adjacent gaseous medium and preferably has a refractive index in the range of from 1.5 to 2.0. A suitable material for the first layer 1 is a glass with a refractive index in the range of from 1.5 to 2.0 or an optical polymer with the outer surface 3 and inner surface 4 being substantially planar and substantially parallel to one another.

As can be seen in the embodiments of Figures 1 and 2 of the accompanying drawings a prism 9 is associated with or attached directly to the outer surface 3 of the first layer 1 to assist in addressing the interface 7 at angles higher than the critical angle. For a glass to air interface 7 the critical angle is 41.8°. The prism 9 is refractive index matched to the material of the first layer and usually made of the same material, and at least minimises refraction at intermediate surfaces. The prism is made of light transparent material, preferably laser light transparent material, and preferably is the same material as that used for the first layer 1. Anti-reflection coatings may be provided on at least the two external faces of the prism 9.

The deformable material of the second layer 5 is at least one of an elastomer, gel, membrane, incompressible fluid, oil film or thermoplastic. In the embodiment illustrated in Figure 1 of the accompanying drawings the material is an elastomer. In this embodiment a third layer 10 is present in the form of a metallic coating, which is non-transparent to light, preferably laser light, on a surface of the second layer 5 which faces the gaseous medium in the gap 6 and forms a boundary therewith to the gap 6. The third layer 10 is an electrode and of sufficient optical density to absorb any transmitted read beam laser light. Preferably the metallic coating forming the third layer 10 is of gold or a gold alloy.

In the first embodiment of Figure 1 the assembly includes a fourth layer 11 adjoining the surface of the second layer 5 most remote from the third layer 10. This fourth layer is made of a

photo conductive material which is at least one of silicon, cadmium sulphide, zinc sulphide, zinc cadmium sulphide and PVK-TNF (a combination of Poly-n-Vinylcarbozol and a dye 2, 4, 7 trinitrofluorenone). The photo conductor PVK-TNF is applied as a thin amorphous film prepared by dissolving PVK (organic Poly-n-Vinylcarbozole) and TNF (a dye 2, 4, 7, trinitrofluorenone) in a suitable solvent such as Tetrahydrofuran.

The assembly of the embodiment of Figure 1 also includes a fifth layer 12 of an electrode material transparent to light, preferably laser light, located adjacent to and in contact with the surface of the photo conductive fourth layer 11 most remote from the second layer 5. The fifth layer 12 is coupled to the third layer 10 via a source of electric energy, conveniently in the form of a D.C. power supply 13. Additionally the assembly of Figure 1 includes a sixth layer 14 of material which is transparent to a write beam 15 of light, preferably laser light. The sixth layer 14 has an inner face 14a adjacent to or in contact with the outer face of the fifth layer 12 most remote from the fourth layer 11. The sixth layer is made of glass or an optical polymer.

The spatial light modulator assembly of the present invention is operable to impose spatial information on a coherent laser light beam. Amplitude modulation of the read in beam 2 is brought about by local spoiling of the total internal reflection condition (TIR) of the beam undergoing total internal reflection at the interface 7 between the first layer 1 and gaseous medium

in the gap 6, which first layer and gaseous medium have differing refractive indices. This spoiling of the total internal reflection condition leads to the condition of frustrated total internal reflection and a local change in the reflection coefficient of the laser beam at that point. In the assembly of Figure 1 on exposure to an incoming write image on the write beam 15 the voltage distribution across the photo conductive fourth layer 11 will change causing a distribution of electro-mechanical forces across the deformable second layer 5. This will cause the second layer 5 to deform in a manner corresponding to the image on the write beam 15 so that the deformation of the second layer 5 modulates the gap 6 above the total internal reflection interface 7 and thus modifies the reflection coefficient at the interface 7. The read in beam 2 striking the interface 7 is thus directly amplitude modulated and reflected at 8.

The optical read beam 2 and write beam 15 may be incoherent or coherent. A collimated read in beam 2 should be incident at the total internal reflection interface 7 at an angle greater than the critical angle for the interface 7. As previously described the critical angle for a glass/air interface is 41.8 degrees. The assembly may operate in either grey-scale or binary mode. Preferably the read in beam is a coherent laser beam and the write beam is an incoherent non-laser light beam.

The assembly of Figure 1 will display memory as long as the spatial charge density variation is maintained at the interface between the second and fourth layers. The photosensitivity of the assembly is determined by suitable choice of the

photoconductive material composing the fourth layer and the extent of deformation is governed by the mechanical properties of the deformable second layer 5. The deformable material for the second layer may be any suitable material which physically deforms in response to an electrostatic field variation. Instead of the elastomer proposed in the Figure 1 assembly for the second layer 5, the layer may be made of a thermoplastic material such as a polystyrene, ester resin or other polymer which is charged with respect to a ground electrode and then exposed to the write beam 15. On subsequent heating of the thermoplastic layer to its softening point it distorts in a fashion corresponding to the image carried by the write beam 15. Erasure of the image may be brought about by heating the thermoplastic layer to a higher temperature.

As a further alternative the deformable material of the second layer 5 may be an oil film, such as polysiloxin on a simple absorbing layer such as an epoxy resin which has a low thermal conductivity, absorbs the write beam light and generates a temperature profile. The heat generated then diffuses through the simple absorbing layer to the contacting oil film which distorts accordingly to modulate the gap 6.

The spatial light modulator assembly forming the second embodiment of the present invention as illustrated in Figure 2 is basically similar to the first embodiment of Figure 1 and like parts have been given like reference numbers and will not be further described in detail. In this second embodiment of Figure 2 the second layer 5 is a membrane coated with a thin metallic

film such as the previously described gold or gold alloy to render the layer 5 an electrode. The assembly includes a spacer layer 16 made of insulating material and provided with a plurality of holes 17 therethrough forming cells or pixels 18 bridged by the second layer 5. The spacer layer 16 is in contact with the surface of the second layer 5 most remote from the gap 6. Additionally the assembly of Figure 2 includes an electrode layer 19 made of electrically conductive material and having a plurality of spaced apart protrusions 20 on one surface thereof forming an array of electrodes. The electrode layer 19 is so located adjacent the spacer layer 16 on the side thereof most remote from the second layer 5 that the electrode protrusions 20 lie one at the base of each hole 17 in the spacer layer 16 so that with the third layer 10 being held at a substantially constant potential and with each electrode protrusion 20 in the array being driven by addressing electronics to a voltage corresponding to a desired value, a potential difference between the electrode protrusions 20 and the third layer 10 causes deflection of the second layer 5 towards or away from the interface 7 to amplitude modulate the read in beam 2 which is reflected as an amplitude modulated read out beam 8.

Preferably the means of address of the assembly 2 is electronic and the read in beam 2 may be incoherent or coherent as previously described. The addressable electrode protrusions 20 may be an array of MOS transistors.

The advantages of the assemblies of Figures 1 and 2 are that the read in beam only sees a flat surface which is the

interface 7 and does not travel through or reflect off a physically deformed surface as in conventional modulator assemblies using a deformable layer. This has the advantage of avoiding beam distortion problems at the reflective interface 7 which remains flat during the operation of the assembly and this also removes any difficult to fulfil requirements for optical quality of the deformable material which is of vital importance in conventional modulator assemblies using deformable materials.

The modulation produced by the assembly is entirely amplitude modulation and is applied directly to the read beam. There is no requirement for subsequent stages to achieve phase to amplitude conversion.

The spatial light modulator assembly of the present invention is suitable for operation by various means of address such as optical or electronic and may either have a large area deformable surface generating an analogue gap modulation or be pixelated utilising deformable elements such as the bridging portions overlying the holes 17 in the Figure 2 embodiment. As the modulation of reflectivity is produced by gap modulation, a wide variety of read out wavelengths is possible.

A spatial light modulator assembly of the present invention is suitable to form the input plane of an optical correlator or the Fourier plane filter for such.

CLAIMS

1. A spatial light modulator assembly of layered sandwich form, including a first layer of material transparent to a read in beam of light, which first layer has an outer surface through which, in operation, an impinging read in beam of light passes into the first layer and an inner surface, a second layer of a deformable material which is physically deformable in response to variation in an electrostatic field, temperature or a potential difference and, located in a gap between the second layer and the inner surface of the first layer, a gaseous medium having a lower refractive index than that of the first layer, which gaseous medium, in operation of the assembly, forms an interface with the first layer inner surface at which the light read in beam passing into the first layer through the outer surface thereof is amplitude modulated by modulation of the gap and thereby of the reflection coefficient at the interface, resulting from deformation from the deformable material, and substantially totally reflected, as an amplitude modulated read out beam, back through the outer surface of the first layer.

2. An assembly according to claim 1, wherein the gaseous medium is air having a refractive index of substantially 1.0.

3. An assembly according to claim 1 or claim 2, wherein the first layer material has a refractive index in the range of from 1.5 to 2.0.

4. An assembly according to claim 3, wherein the first layer material is glass or an optical polymer, and wherein the outer and inner surfaces are substantially planar and substantially parallel to one another.

5. An assembly according to any one of claims 1 to 4, including a prism made of light transparent material substantially refractive index matched to the first layer material and associated with or attached to the outer surface of the first layer to assist in addressing the interface at high angles and reducing refraction.

6. An assembly according to claim 5, including anti-reflection coatings on at least the two external faces of said prism.

7. An assembly according to any one of claims 1 to 6, wherein the second layer deformable material is at least one of an elastomer, gel, membrane, incompressible fluid, oil film or thermoplastic.

8. An assembly according to claim 7, including a third layer in the form of a metallic coating, which is non-transparent to light, on a surface of the second layer which faces the gaseous medium and forms a boundary therewith to the gap, which third layer is an electrode and of sufficient optical density to absorb any transmitted read in beam light.

9. An assembly according to claim 8, wherein the metallic coating is made of gold or a gold alloy.

10. An assembly according to claim 8 or claim 9, including a fourth layer adjoining the surface of the second layer most remote from the third layer, which fourth layer is made of a photoconductive material.

11. An assembly according to claim 10, wherein the fourth layer material is at least one of silicon, cadmium sulphide, zinc sulphide, zinc cadmium sulphide and PVK-TNF (a combination of Poly-n-Vinylcarbozole and a dye 2, 4, 7 trinitrofluorenone).

12. An assembly according to claim 10 or claim 11 including a fifth layer of an electrode material, transparent to light, located adjacent to and in contact with the surface of the photoconductive fourth layer most remote from the second layer, which fifth layer is coupled to the third layer by a source of electrical energy..

13. An assembly according to claim 12, including a sixth layer of a material which is transparent to a write beam of light, which sixth layer has an inner face adjacent to or in contact with the outer face of the fifth layer most remote from the fourth layer.

14. An assembly according to claim 13, wherein the sixth layer is made of glass or an optical polymer.

15. An assembly according to claim 8, wherein the second layer is a membrane.

16. An assembly according to claim 15, including a spacer layer made of insulating material and provided with a plurality of holes therethrough forming cells or pixels bridge by said second layer, which spacer layer is in contact with the surface of the second layer most remote from the gap.

17. An assembly according to claim 16, including an electrode layer made of electrically conductive material and having a plurality of spaced apart protrusions on one surface thereof forming an array of electrodes, which electrode layer is so located adjacent to said spacer layer on the side thereof most remote from the second layer, that the electrode protrusions lie one at the base of each hole in the spacer layer, so that with the third layer being held at a substantially constant potential and with each electrode in the array being driven by addressing electronics to a voltage corresponding to a desired value, a potential difference between the electrodes and the third layer causing deflection of the second layer towards or away from the interface to amplitude modulate the read out beam.

18. An assembly according to any one of claims 1 to 17, wherein the read in beam and/or read out beam is or are of laser light.

19. A spatial light modulator assembly, substantially as hereinbefore described and as illustrated in Figure 1 or Figure 2 of the accompanying drawings.

Patents Act 1977
Examin r's report to the Comptroller und r Section 17 (The Search Report)

Application number

9205660.5

Relevant Technical fields

(i) UK Cl (Edition K) G2F (FCH)

(ii) Int Cl (Edition 5) G02B G02F

Search Examiner

G M PITCHMAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS

Date of Search

24 JULY 1992

Documents considered relevant following a search in respect of claims 1 TO 19

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2238880 A (GEC-MARCONI) - see Figure 1	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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&: Member of the same patent family, corresponding document.

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